Distribution of Amphipods and Isopods Trapped from the Water Column in the Vicinity of the Kraft Mill at Port Mellon, British Columbia

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DISTRIBUTION OF AMPHIPODS AND ISOPODS TRAPPED FROM THE WATER COLUMN IN THE VICINITY OF THE KRAFT MILL AT PORT MELLON, BRITISH COLUMBIA

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ABSTRACT

Greer, G. L., and P. G. Futer. 1979. Distribution of amphipods and isopods trapped from the water column in the vicinity of the kraft mill at Port Mellon, British Columbia. Fish. Mar. Serv. Tech. Rep. 909: 21 p.

The distribution of epibenthic invertebrates present in the intertidal water column was determined in the vicinity of the kraft mill at Port Mellon, British Columbia, during the summers of 1977 and 1978. Animals were trapped at nine stations by suspending at mid-tide height mesh bags containing *Fucus* sp. as the colonization substrate. Temperature and color of the surface water was measured at the trapping stations to estimate the distribution of effluent in the intertidal area. The amphipod *Eogammarus confervicolus* and the isopod *Gnorimosphaeroma oregonensis* were the most frequently occurring species. During periods of routine mill operation, the distribution of numbers of *E. confervicolus* and *G. oregonensis* in relation to distance from the mill was generally inversely correlated with the distribution of temperature and apparent effluent levels. The main impact area was within close proximity of the effluent outfalls.

Key Words: Amphipods, isopods, kraft mill effluent, Port Mellon.

RÉSUMÉ

Greer, G. L., and P. G. Futer. 1979. Distribution of amphipods and isopods trapped from the water column in the vicinity of the kraft mill at Port Mellon, British Columbia. Fish. Mar. Serv. Tech. Rep. 909: 21 p.

On a déterminé la distribution des invertébrés épibenthiques présents dans la colonne d'eau intertidale à proximité de la fabrique de pâte kraft de Port Mellon (Colombie-Britannique), au cours des étés de 1977 et 1978. Pour capturer les animaux, on a suspendu à hauteur de mi-marée, à neuf stations, des sacs de filets qui contenaient des *Fucus* spp. servant de substrat de colonisation. La température et la couleur des eaux superficielles ont été mesurées aux stations de capture afin que soit déterminée la distribution des effluents dans la région intertidale. L'amphipode *Eogammarus confervicolus* et l'isopode *Gnorimosphaeroma oregonensis* étaient les espèces les plus courantes. Pendant les périodes de fonctionnement normal de la fabrique, la distribution des colonies de *E. confervicolus* et de *G. oregonensis* par rapport à leur distance de la fabrique présentait en général une corrélation inverse avec la répartition de la température et de la concentration apparente des effluents. La zone la plus touchée se trouvait à proximité de la sortie des effluents.

Mots clés: amphipodes, isopodes, effluents de fabrique de pâte kraft, Port Mellon.

INTRODUCTION

Utilization of intertidal and estuarine areas in British Columbia by the forest products industry and commercially important fish stocks has been a continuing concern in management of the fishery resource. The possible impact of pulp mill effluents on the intertidal area has been of particular interest and the focal point of much biologically-oriented work.

A number of studies have been undertaken to determine the effects of pulp mill effluent on specific intertidal organisms and communities. Peer (1972) conducted a faunal survey before and after construction of a kraft mill in Nova Scotia and partly attributed the observed changes in faunal composition to the effect of mill effluent. Harger at al. (1973) noted density changes of six invertebrate species with increasing distance from the effluent outfall of the kraft mill at Port Alberni, B.C. Transfer experiments, in which selected intertidal organisms from an area outside mill influence were relocated to a point adjacent to the mill outfalls, indicated some deleterious effect of the effluent on the relocated organisms (Harger et al. 1973). In similar experiments (Wu and Levings, in press), the growth rate of adult mussels (*Mytilus edulis*) and barnacles (*Balanus glandula*) transplanted near the outfalls of the Port Mellon kraft mill was retarded and the fecundity of the transplanted barnacles impaired. Harger and Nassichuk (1974) observed changes in density of amphipod and isopod populations with distance from the outfalls of this mill. In a laboratory experiment, Levings et al. (1976) described a synergistic relationship between kraft mill effluent and salinity on amphipod survival. Thus, pulp mill wastes are implicated as a causative factor in changes in intertidal communities adjacent to mill sites.

Studies have often focused on abundance and distribution patterns of epibenthic invertebrates due to the importance of these organisms as potential fish food items. Quadrat sampling of the intertidal region has been the usual method of investigation. More recently a trapping method developed by Levings (1976) permits estimation of the relative numbers of epibenthic invertebrates in the water column where they would be more available to foraging juvenile salmonids. Using the method of Levings (1976), the current study was undertaken to determine the impact of kraft mill effluent on the distribution of two epibenthic invertebrate species in the water column in the vicinity of the Port Mellon pulp mill.

MATERIALS AND METHODS

Study Area

The study area was located along the west shore of Thornbrough Channel in Howe Sound and extended about 0.8 km north and 1.5 km south of the Port Mellon kraft pulp mill operated by Canadian Forest Products Ltd. (Fig. 1). The mill site is bounded on either side by three rivers. Rainy River is located at the northern limit of the study area and provides the source of fresh water used by the mill. McNair Creek and Dakota Creek form a confluence about 100 m inland and enter Thornbrough Channel via a common course about 1 km south of the mill site. A log storage and booming ground not under the jurisdiction of Canadian Forest Products Ltd. extends approximately 2 km southwards from the mill. The log storage area is left open off the mouth

of Dakota and McNair Creeks.

Eight trapping stations were located in the study area in 1977; a ninth station (FD) was added in 1978. The intertidal habitat along the southern shoreline from Stn. L-8 to Stn. F-8 (Fig. 1) consists of barnacle covered rocks and is bordered above high tide line by a gentle slope of grasses. At the mouth of Dakota-McNair Creeks, sedge (*Carex* sp.) is present in the upper third of the intertidal zone. Between Stn. OD and northeast to Stn. FD (Fig. 1), the intertidal area is covered by a mat of wood fiber and lime mud. Stn. C was located over deep water at the northern end of the dock used for loading deep sea vessels and adjacent to a stablizing wall of boulders. Stn. B was adjacent to a gravel beach about 100 m north of the mouth of Rainy River and away from the direct influence of the freshwater inflow.

Stn. FD was located mid-way between the alkaline and bleach outfalls. For the purpose of plotting data in the figures, distances to the other stations were taken as a straight line from Stn. FD.

Mill operation

The mill uses hemlock, fir and cedar wood chips digested in a solution of caustic soda and caustic sulfide in a ratio of approximately 4:1 (kraft process). In the production of fully bleached pulp, the bleaching sequence consists of five stages: chlorination, first caustic extraction, first chlorine dioxide, second caustic extraction, and second chlorine dioxide. The rated production capacity for fully bleached pulp is 550 air dry tons per day. The mill also produces unbleached and semi-bleached pulp employing fewer stages in the bleaching sequence.

Alkaline waste is discharged via a 0.75 m diameter pipe into a ditch on the beach. The bottom of the pipe is at an elevation of about 1.2 m relative to tidal heights at Point Atkinson, B.C., and is submerged at tidal heights exceeding approximately 2 m. The acid bleach waste pipe leads into a small lagoon and discharges at a depth approximately 4.5 m below low tide level. The two outfalls are separated by about 150 m. The combined discharge from the two sewers is of the order 113×10^6 L/day. At the discharge point in summer, the temperatures of the alkaline and bleach wastes are 26-27 C and $\sim$ 40 C, respectively (D. Chance, Can. For. Prod. Ltd., pers. comm.)

Epibenthic organisms present in the water column at varying distances from the mill outfalls were sampled using traps similar to the type developed by Levings (1976). The traps consisted of drawstring net bags (25 cm wide x 32 cm long; 15 mm mesh) loosely packed with *Fucus* sp. which served as the colonization substrate. The *Fucus* had first been thoroughly washed in warm fresh water to remove any organisms present. A small stone was added to each bag to give the traps sufficient weight to keep them suspended in the water column during tidal fluctuations. In the field, the traps were attached to vertical pilings at tidal heights of 1.3-1.6 m above chart datum. At these tidal heights, the traps were at a distance of 10 m or less from the shoreline. Suspending the traps on $\sim$ 1 m lengths of cord permitted retrieval at tides of up to 3 m height. Once set, traps were left in place for 12-14 d during the 1977 portion of the study and for 7-9 d in 1978.

When the traps were collected they were placed in individual plastic bags and returned to the laboratory where they were stored at 3 C prior to processing. Processing entailed washing the contents of each trap over stacked screens of mesh size 4.0 mm, 2.83 mm and 0.5 mm. Organisms picked from the two screens of largest mesh size plus the entire contents of the smallest screen were stored in 10% formalin. Amphipods and isopods were sorted to genus and enumerated under a magnifying glass or, when required, a dissecting microscope. Species identification was confirmed using several taxonomic keys (Bousefield 1958, 1979; Smith and Carlton 1975; Staude et al 1977). The washed *Fucus* was dried at 100 C for 48 h and weighed. Density of organisms colonizing the traps (no./g dried *Fucus*) is expressed simply as the average where more than one set was made.

Trapping periods

The study was undertaken in the summer months of 1977 and 1978. In 1977 two trap sets were made in the period May 20-June 17 during "routine" mill operation. In 1978 the study was divided into 3 phases comprising a total of 6 trap sets. The first phase was carried out June 13-30 while the mill was in full operation (2 sets). The second phase was July 11-18 during the second week the mill was closed for maintenance (1 set) and the third phase was during August 9-23 when the mill was again operating routinely (2 sets).

Water and effluent sampling

In 1978 only, some water sampling was carried out during the latter part of the study in an attempt to estimate the distribution of effluent over the study area. Color and temperature of the surface waters (3-5 cm depth) was determined at intervals for each trapping station. Color was measured by the visual comparison method using PtCo color standard (APHA 1971). Color of the three freshwater streams was determined in the main course of each stream well above tidal influence. Color of the composite effluent, which is representative of the combined alkaline and bleach wastes discharged by the mill, was determined from samples collected from the separate process streams and composited in the following proportions: alkaline 68%, 1st caustic 2%, combined bleach 30%. The combined bleach consisted of the following mixture of bleach plant streams: chlorine 60.4%, 1st chlorine dioxide 24.8%, and 2nd chlorine dioxide 14.8%.

RESULTS

Shoreline effluent distribution and stream water color

Shoreline effluent distribution: The color and temperature measured in the surface tidal waters during the 1978 pre- and post-maintenance periods of routine mill operation decreased with greater distance from the mill outfalls indicating a diminished presence of effluent along the shoreline (Fig. 2 A,B). Station S (Fig. 1) was under the direct influence of the Dakota-McNair Creek system and the temperatures at this station (Fig. 2B) reflect the progressive warming of these streams over the summer season. On July 1 the mill was

closed for maintenance and on the eleventh day following shutdown, low colors present throughout the study area (6-24 APHA units, Fig. 2A) indicated that most of the mill effluent had dispersed by this time. Of the color remaining, especially south of the mill, it is possible some derived from Dakota Creek where colors were consistently high (Table 1) or from the leaching of logs contained in the extensive booming grounds along the shore. At distances greater than about 1 km north and south of the mill outfalls, color levels during routine mill operation decreased to the levels present at all stations after the mill had been down for 11 days (Fig. 2A). Thus, the presence of mill effluent seems largely confined to this 2 km length of shoreline.

Both temperature and color of the shoreline surface waters were substantially higher during the post-maintenance period than during premaintenance (Fig. 2A,B). The higher apparent effluent levels do not appear to have been caused by changes in mill activity because daily production rates were similar for both periods (D. Chance, Can. For. Prod. Ltd., pers. comm.). The weather during the August portion of the study was generally inclement, however, and deteriorated frequently bringing winds from the southeast. Southeast winds are on-shore in the vicinity of the mill and would tend to trap surface waters along the shore. It seems likely, therefore, the higher colors and temperatures resulted from impeded circulation and flushing of the shoreline area.

Stream water color: The color of water collected at intervals from the three streams adjacent to the mill during the latter part of the 1978 study indicates that modest amounts of color from non-mill sources were usually added to the study area compared to the intense color added by the mill effluent (Table 1). In the period July to mid-August, the weather was relatively dry and the color of all three streams was lower than during the latter part of August when the weather was unsettled and rainfall more frequent. A brown stain was usually apparent in Dakota Creek water and accounts for the consistently higher color values for this stream. On August 24, a particularly high color value of 125 APHA units was recorded in Dakota Creek, equivalent to approximately 5-10% of the range of colors found for the mill effluent (Table 1). This high color resulted from heavy rainfall and occurred together with high stream flows. Although the addition of color to tidal waters from this stream could be appreciable when heavy rainfall prevails, the effect would be lessened by dilution of Dakota Creek water at its confluence with McNair Creek about 150 m inland (Fig. 1). Thus under most conditions stream-originating color would add only minimally to that attributable to the mill.

Amphipod and isopod distribution

The main species of epibenthic invertebrates colonizing the bag traps during both the 1977 and 1978 portions of the study were the amphipod *Eogammarus confervicolus* and the isopod *Gnorimosphaeroma oregonensis*. Another isopod (*Idotea wosnesenskii*) and several species of amphipods (*Hyale anceps*, *Corophium* sp., *Ampithoe valida*, *Paramoera columbiana*) were found infrequently and in low numbers but when present were usually at the outlying stations. These latter species are not included in the data presented below.

During routine mill operation: During the period May 20-June 17, 1977, the numbers of amphipods trapped from the water column was variable but tended to

increase with greater distance from the mill (Fig. 3A). Amphipod density was substantially reduced only within close proximity to the mill outfalls (Stations C, OD, F-8; Fig. 3A). The distribution of isopods in relation to distance from the mill was similar, with the lowest density also occurring in closest proximity to the mill outfalls (Stn. OD). Unlike the amphipods, however, the increase in numbers of isopods became very substantial at stations close to the mill outfalls (i.e. Stations C and F-8; Fig. 3B).

In 1978, the distribution of amphipods and isopods in relation to distance from the outfalls during routine mill operation (June 13-30 and August 9-23) was similar to that found in 1977. For those stations where temperature and color of the surface waters indicated the presence of mill effluent (Stns. G-10 to C inc., Fig. 2A,B), the distribution of both species was generally inversely correlated (shaded columns, Fig. 4A, C and 5A, C).

The numbers of amphipods and isopods trapped from the water column were smaller in 1978 than in 1977 and is probably accounted for by the shorter period the traps were set out (7-9 days in 1978, 12-14 days in 1977).

During mill shutdown: In 1978, the trap set starting on the eleventh day after the mill had gone down for maintenance indicated that greater densities of amphipods were in the water column at most stations including three of the five stations normally under the influence of high temperature and apparent effluent levels during mill operation (Stns. C, FD, OD; Fig. 4B). Elevated numbers of isopods were present at all stations except Stn. C but the greatest increases occurred at the southern Stns. S, J-2, and L-8 (Fig. 5B).

Post-maintenance: The results of the trap set for the post-maintenance period (August 9-23, 1978) show a general decrease in numbers of amphipods and isopods relative to the numbers present during mill shutdown (Fig. 4C, 5C). In addition, before mill shutdown (June 13-30), the southern limit of the area in proximity to the outfalls having the greatest reduction in numbers of amphipods and isopods in the water column extended to station OD but in the post-maintenance period (August 9-23) the adjacent station F-8 also showed this reduction. Notably, higher colors (Fig. 2A) and higher temperatures (Fig. 2B) were present at these stations in August than had been observed prior to shutdown.

The 1978 results were subjected to the Kruskal-Wallace test for ranked data (Sokal and Rohlf 1969) to compare the amphipod and isopod numbers occurring at the stations beyond the presence of mill effluent (L-8,J-2, S,B) with those stations where effluent was present during mill operation (G-10, F-8, OD, FD, C). The data were further partitioned according to the periods of low (June 13-30) and high (August 9-23) apparent effluent levels (Fig. 2A) as shown in the array of ranked sums below:

	Treatment (a=3)		
	no effluent	low effluent	high effluent
amphipods	416.5	151.5	97.5
isopods	396.5	152.5	117.5
n	16	10	10

The numbers of both species were significantly ($P<0.01$) smaller at the stations where effluent was present. The rank sums also indicate the numbers of organisms were fewer when apparent effluent levels were higher but the difference is not significant.

DISCUSSION

While high color and temperature are both characteristics of the effluent discharged from the Port Mellon kraft mill, color in particular is the better indicator of effluent dilution in the intertidal waters of the study area because contributions from non-mill sources (i.e. the freshwater streams adjacent to the mill) were comparatively small (Table 1). Although color is pH dependent and increases with higher pH (APHA 1971), the buffering capacity of marine receiving waters should make effluent color a reasonably conservative property. Temperature, on the other hand, is a non-conservative property in stratified inlet waters and perhaps is better used in the present study as an additional physical descriptor of shoreline water habitat. Nevertheless, the similarily between the color and temperature distribution curves (Fig. 2A, B) indicates that a substantial portion of the surface water temperature stems from the warm effluent discharged by the mill.

In the intertidal areas extending either side of the pulp mill where the presence of effluent was indicated by higher colors and temperatures, numbers of amphipods and isopods were generally inversely correlated with these two factors. Still, substantial increases in density within the effluent area usually occurred at stations adjacent to those showing very low densities (Fig. 4A, C; 5A, C). Thus, there may exist a range of temperature and effluent levels acting singly or in combination which restricts utilization of the water column by these organisms. As temperature and effluent levels decrease below this range, the numbers of amphipods and isopods in the water column may then vary according to some other habitat factor(s), for example, substrate quality, availability of cover, or optimum salinity.

Several habitat factors have been found to be related to the distribution of amphipods but similar information appears lacking for isopods. Levings and Levy (1976) found the distribution of *A. confervicolus* in the Squamish estuary closely related to vegetation patterns, particularly of the sedge, *Carex lyngbyei*. Low salinity conditions ($\sim 15^{o}/oo$) have been shown to be optimum for the survival of *E. confervicolus* in the laboratory (Pomeroy and Levings, in press) and their distribution in the field may at least partly reflect salinity gradients. Levings et al. (1976) also suggested from laboratory experiments a synergistic relationship between effluent and salinity; the combination of high salinity ($27-28^{o}/00$) and effluent concentration (21-24%) was especially toxic to *E. confervicolus*. During mill operations, a salinity-effluent synergism would be unlikely in close proximity to the outfalls since salinity would be low because of the freshwater nature of the effluent. However, the lack of suitable substrate and cover due to the extensive fiber and lime mud beds in this area (Stn. OD, FD, Fig. 1). could have contributed to the low densities observed since some of the animals occupying the water column must be derived from local populations residing on the substrate.

Given the lack of suitable substrate in close proximity to the outfalls and the low salinity, which for amphipods would be favorable for survival, the

high temperature and effluent levels near the outfalls would remain as the most likely factors responsible for the low numbers of these organisms moving into the outfall area from adjacent habitat. The changes in density of both species in the near vicinity of the outfalls indicate a main impact area bordered by Stns. C and F-8 was present in June but extended farther south to Stn. G-10 in August (Fig. 4C, 5C). Assuming color to be a conservative property, an estimate of effluent concentration having a boundary effect on utilization of the water column by these organisms can be made from a simple ratio of surface water color at the boundaries of the main impact area and color of effluent discharged from the mill. Using a mean effluent color of 2110 APHA units obtained from the data in Table 1, the apparent effluent concentration at Station C was about 6% in the June 13-30 period of mill operation and about 9% in August. At the southern boundary of the main impact area in June (Stn. F-8), the apparent effluent concentration was about 9% and in August when the main impact area extended to Stn. G-10 was also about 9%. The temperatures at those stations bordering the main impact area for the June and August periods (Fig. 2B) exceed the temperature ($\sim$ 10 C) suggested for optium survival of *E. confervicolus* in the laboratory (Levings et al. 1976). It should be kept in mind, however, these estimates of temperature and effluent concentrations indicative of the two trapping periods are for the surface layer of water only. Apparent effluent levels and temperatures would be lower with depth because of vertical mixing in the water column. Thus, if some range of effluent concentrations and temperatures did limit utilization of the water column by these organisms, it may be less than those estimated here.

The suggestion of restricted utilization of the water column by amphipods and isopods close to the mill outfalls appears anomalous to the findings of Harger and Nassichuk (1974) in an earlier study at Port Mellon. Using a variant of the quadrat sampling method, they reported densities of *E. confervicolus* and *G. oregonensis* under rock cover in the intertidal area ($\sim$1 m above mean low water) to be higher closer to the effluent outfalls (near Stn. F-8 of present study) than farther away. A similar trend in density of these species under cover was observed adjacent to the Port Alberni, B.C., pulp mill (Harger et al. 1973). However, the numbers of epibenthic organisms trapped from the water column near the sulfite mill at Port Alice, B.C. (Greer and Futer 1979) showed the trend found in the present study. Levings (1976) compared amphipod density under cover in the intertidal area of the Cowichan and Squamish estuaries with amphipod density in the water column at adjacent sites using quadrat and *Fucus* bag trap sampling techniques, respectively. The same amphipod distribution pattern was found with either technique used. Thus, in an area where there is not an apparent gradient of habitat quality, the proportion of the amphipod population under cover compared to the proportion occupying the water column was approximately constant. Harger and Nassichuk (1974) postulated the higher densities of amphipods and isopods closer to the Port Mellon mill were due to the inability of predators and competitors to survive under the adverse conditions present but which amphipods and isopods could withstand. An alternate view in light of the findings in this study could be that, outside the main inpact area and where bottom cover is accessible, the size of the population does not change appreciably with distance from the mill but the presence of higher temperature and effluent levels closer to the mill induces greater cover-seeking behavior. This behavior would result in a smaller proportion of animals in the water column. Given stratification of the water column, the greatest effluent

contamination would be in the surface layers and animals maintaining cover on bottom substrate would reduce their exposure to effluent as well as the higher temperatures associated with effluent discharge.

The reduced number of amphipods available in the water column for cropping by juvenile salmonids adjacent to the mill points to an indirect effect of mill effluent on salmonids. However, beach seine catches indicate few salmonids frequent the areas adjacent to the Port Mellon mill (Birtwell and Harbo 1979). In addition, the surface waters within 350 m of the outfalls are acutely toxic to juvenile salmonids (Birtwell and Harbo 1979). Thus it is likely that degraded water quality is a more likely factor influencing salmonid distribution adjacent to the outfalls than availability of food items.

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Table 1. Pulpmill and non-mill sources of color (APHA units) added to the study area intertidal waters, 1978.

Sample collection date	Pulpmill composite effluent	Freshwater streams		
		Rainy River	McNair Creek	Dakota Creek
July 11	mill down	5	4	35
August 09	2,833	0	0	15
August 11	2,500	8	0	16
August 17	2,000	13	3	54
August 21	1,625	5	7	50
August 23	2,500	7	5	30
August 24	1,200	25	28	125

Figure 1. Study area and location of stations used in trapping amphipods and isopods from the water column near the Port Mellon kraft mill, 1977 and 1978.

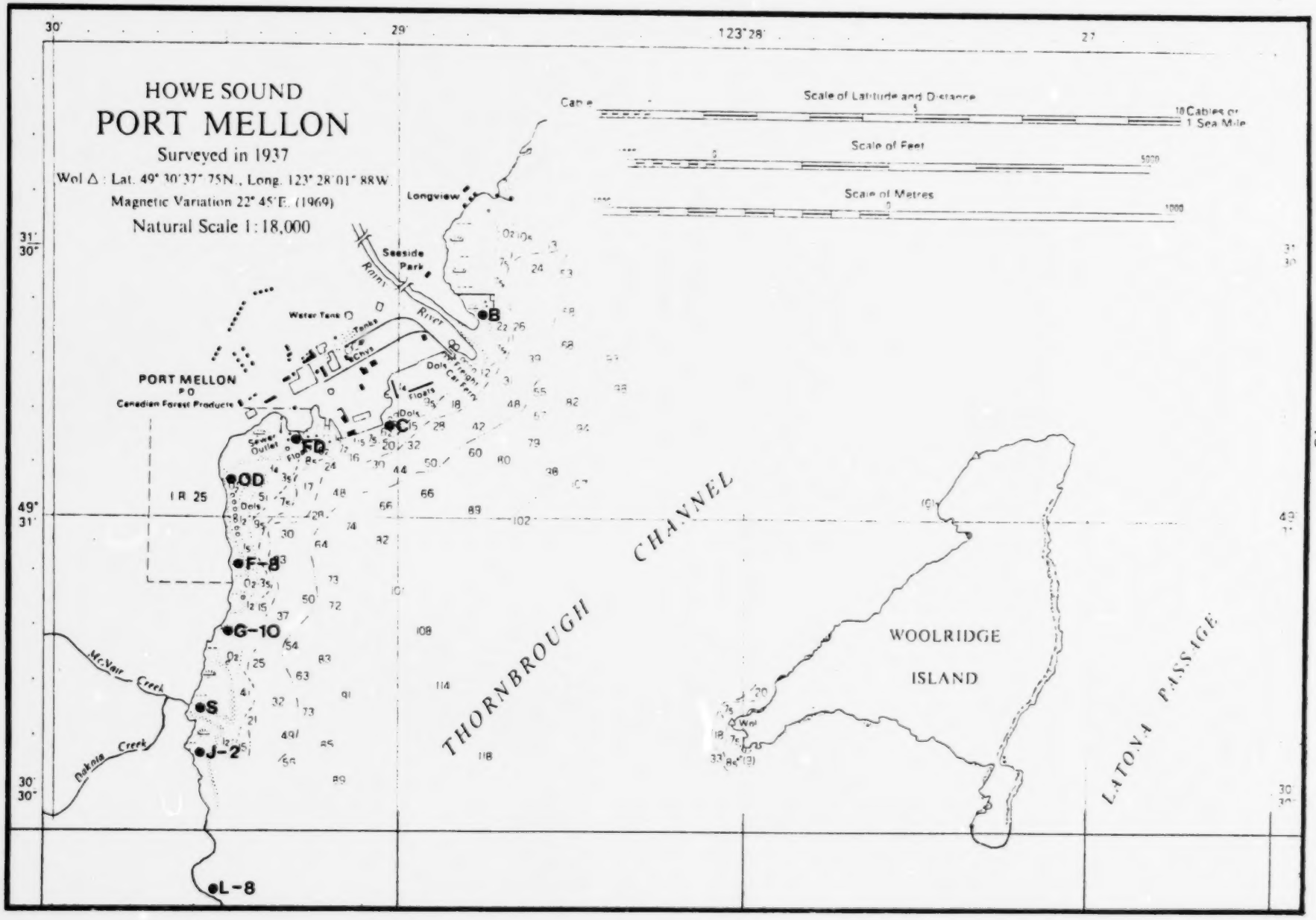
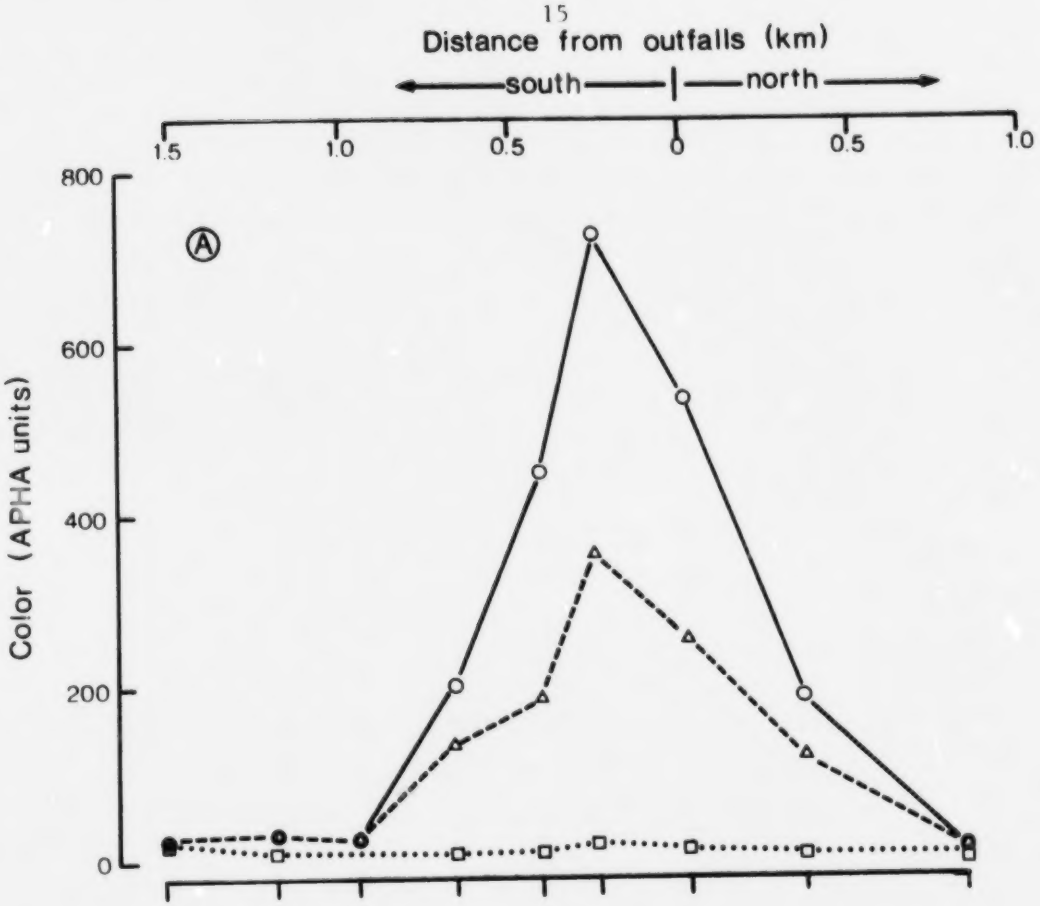

HOWE SOUND
PORT MELLON
Surveyed in 1937
Wol Δ : Lat. 49° 30' 37" 75N., Long. 123° 28' 01" 88W.
Magnetic Variation 22° 45'E. (1969)
Natural Scale 1:18,000
Scale of Latitude and Distance
Scale of Feet
Scale of Metres
Longview
Seaside Park
Water Tank
Tanks
Chute
Dole Car Ferry
PORT MELLON
P.O.
Canadian Forest Products
Sewer Outlet
Floats
Dols
I.R. 25
McNair Creek
Daknia Creek
THORNBROUGH CHANNEL
WOOLRIDGE ISLAND
LATONA PASSAGE
B
C
FD
OD
F-8
G-10
S
J-2
L-8

Figure 2. Distribution of surface water color (A) and temperature (B) north and south of the Port Mellon kraft mill in 1978.

(--△----△---) during routine mill operation, June 13-22

(····□····□····) during mill shutdown, July 11-23

(—O——O—) during post-maintenance mill operation, August 9-16.


Distance from outfalls (km)
south
north
1.5
1.0
0.5
0
0.5
1.0
800
600
400
200
0
Color (APHA units)
A

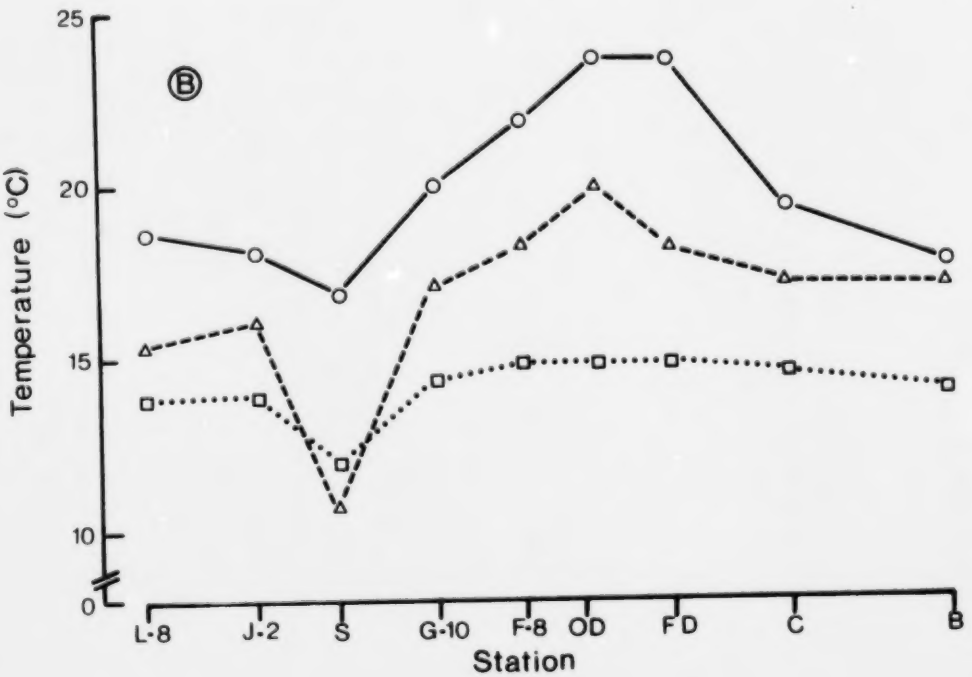

25
20
15
10
0
Temperature (°C)
B
L-8
J-2
S
G-10
F-8
OD
FD
C
B
Station

Figure 3. Density (no. organisms/g dried *Fucus*) of amphipods (A) and ispods (B) in relation to distance from the Port Mellon kraft mill outfalls, May 20 - June 17, 1977.

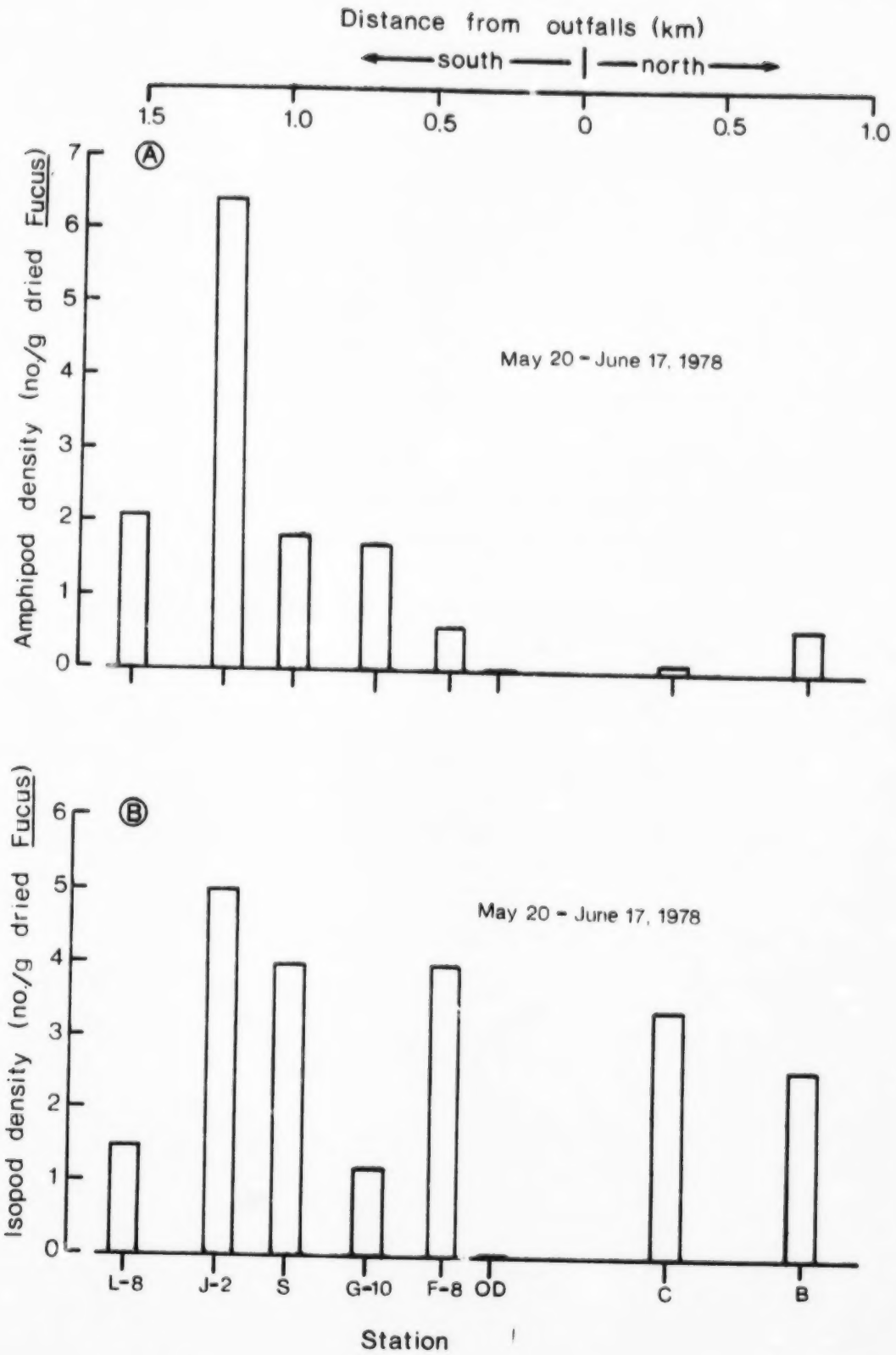

Distance from outfalls (km)
south
north
1.5
1.0
0.5
0
0.5
1.0
Ⓐ
Amphipod density (no/g dried Fucus)
0
1
2
3
4
5
6
7
May 20 - June 17, 1978
Ⓑ
Isopod density (no/g dried Fucus)
0
1
2
3
4
5
6
May 20 - June 17, 1978
L-8
J-2
S
G-10
F-8
OD
C
B
Station

Figure 4. Density (no. organisms/g dried *Fucus*) of amphipods in relation to distance from the Port Mellon kraft mill outfalls during three periods in 1978.

The shaded bars are for stations under the influence of mill effluent.

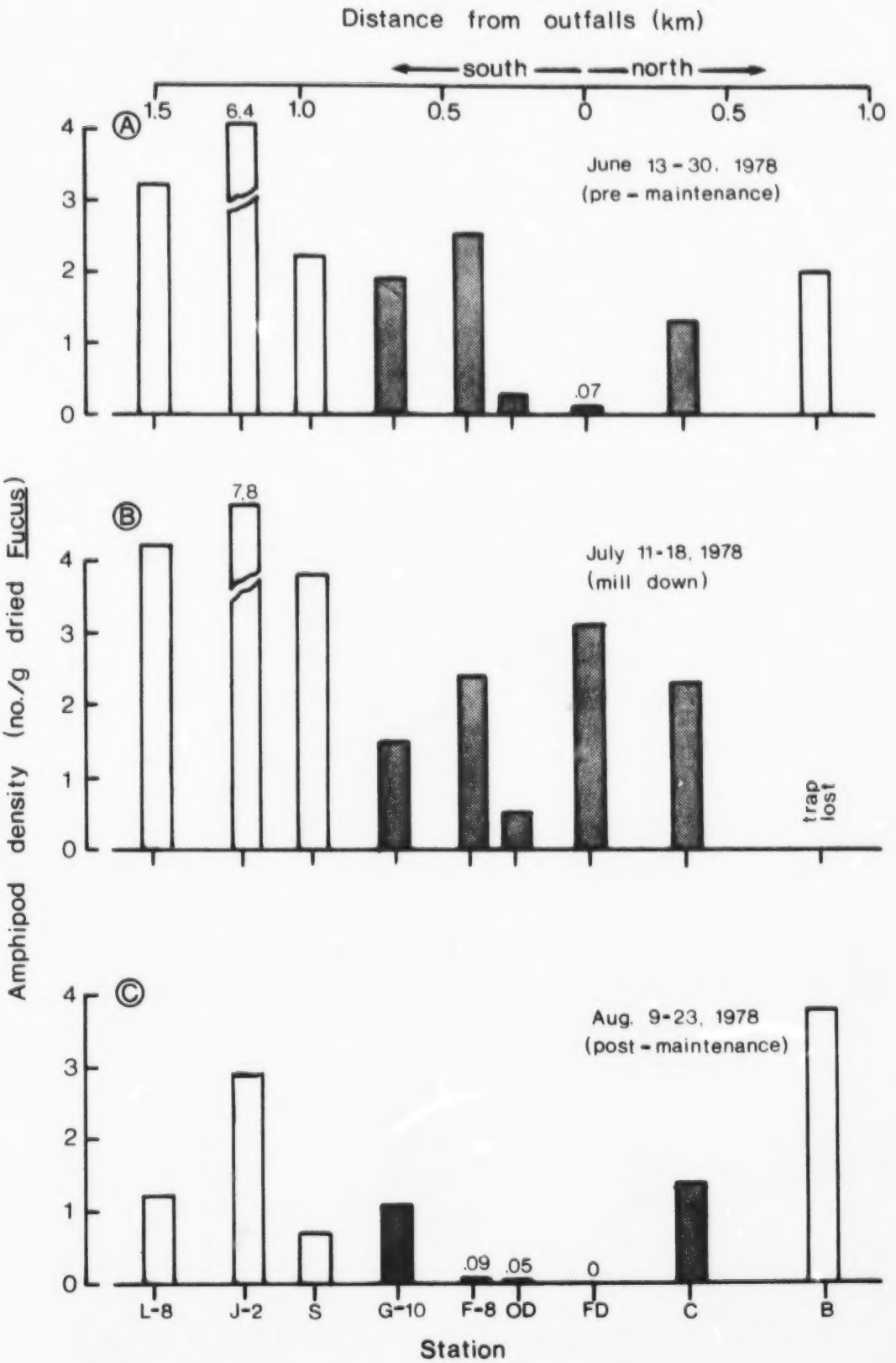
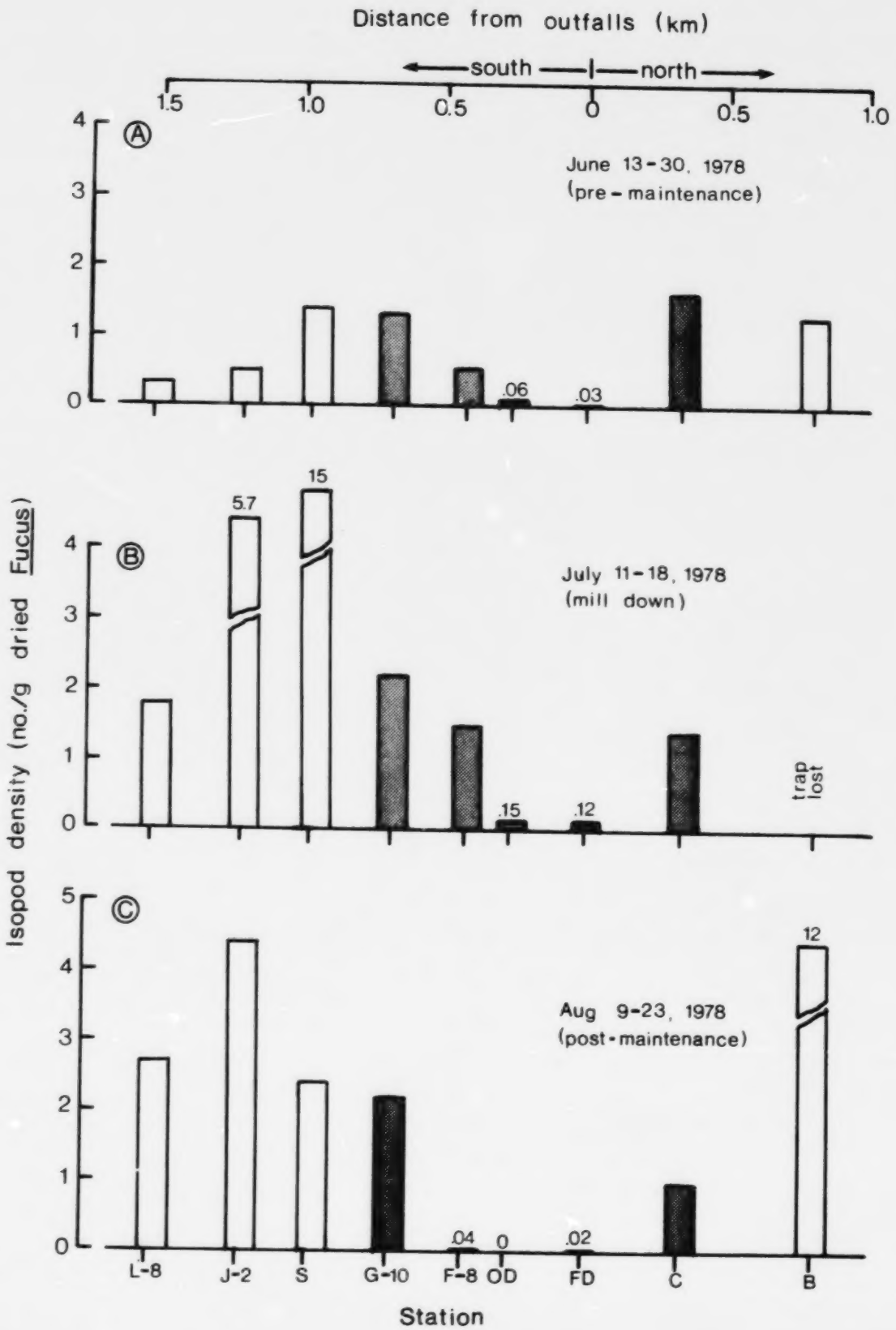

Distance from outfalls (km)
south
north
1.5
6.4
1.0
0.5
0
0.5
1.0
A
June 13 - 30, 1978
(pre - maintenance)
.07
B
7.8
July 11-18, 1978
(mill down)
trap lost
C
Aug. 9-23, 1978
(post - maintenance)
.09
.05
0
Amphipod density (no./g dried Fucus)
0
1
2
3
4
L-8
J-2
S
G-10
F-8
OD
FD
C
B
Station

Figure 5. Density (no. organisms/g dried *Fucus*) of isopods in relation to distance from the Port Mellon kraft mill outfalls during three periods in 1978.

The shaded bars are for stations under the influence of mill effluent.


Distance from outfalls (km)
south
north
1.5
1.0
0.5
0
0.5
1.0
Ⓐ
June 13-30, 1978
(pre-maintenance)
.06
.03
Ⓑ
5.7
15
July 11-18, 1978
(mill down)
.15
.12
trap lost
Ⓒ
12
Aug 9-23, 1978
(post-maintenance)
.04
0
.02
Isopod density (no./g dried Fucus)
L-8
J-2
S
G-10
F-8
OD
FD
C
B
Station